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Development of Decision making model using Integrated AHP and DEA for Vendor selection

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Abstract

In today's highly competitive and interrelated manufacturing environment, effective selection of suppliers is very important to the success of a manufacturing firm .Evaluating and selecting the best among the offers provided by various suppliers is a complex problem that takes into account both tangible and intangible criteria's. This paper considers supplier selection as a multi-criterion decision problem. Data envelope analysis (DEA) is used in this paper to generate local weights of alternatives from pair-wise comparison judgment matrices used in the analytical hierarchy process (AHP).The local weights generated using DEA are being aggregated using the AHP procedure.
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1. Introduction

1.1 Importance of vendor selection

Purchasing decisions have a profound impact on the success of the companies since the cost of purchased goods and services account for more than 50% of the cost of products sold. Purchasing decisions also play a major role in deciding the quality of the final products. The key objective of the purchase department is to purchase the right quality of material in the right quantity from the right source at the right time. The right source is one which can provide the right quality of material on time at a reasonable price. Selection of a wrong vendor or source could be enough to upset the company's financial and operational position. Traditionally vendors are selected on their ability to meet the quality requirements, delivery schedule and the price offered. However, in modern management, one needs to consider many other factors with the aim of developing a long-term vendor relationship. Vendors are considered as the best intangible assets of any organization.

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Strong competitive pressure forces many organizations to provide their products and services to customers faster, cheaper and better than the competitors. Managers have come to realize that they cannot do it alone without satisfactory vendors Therefore, the increasing importance of supplier selection decisions is forcing organizations to rethink their purchasing and evaluation strategies and hence the selection of suppliers has received considerable attention.

1.2 Literature Review

The problem of supplier selection has been researched abundantly. Dickson (1966) identified over 20 supplier attributes, such as net price ,quality, delivery and service .The simplest method is the categorical method, which assigns good, satisfactory , neutral, and unsatisfactory to each supplier characteristic and sums up to total score for each supplier (Godsypour and O'Brien, 1998). Weber (1996) applied DEA for a single product and proposed a model to use it for supplier selection for other products also. Talluri and Narasimhan (2005) designed a linear programming model to help decision makers or buyers select and evaluate different suppliers Talluri (2002) proposed a binary integer linear programming model for evaluating alternative supplier bids. Karpak et al. (2001) are the first group of researchers who proposed goal programming (GP) model to evaluate the suppliers. Quality, cost, and delivery performance were the three identified objectives. Narasimhan et al. (2006) developed a multi-objective programming model to solve supplier selection problem and came out with the optimal order quantity. Chan and Chan (2004) used AHP hierarchy to evaluate and select suppliers. Choy and Lee (2002) proposed a generic model of CBR integrating customer relationship management (CRM) and supply chain management (SCM) to identify appropriate supplier for the products, services and distribution. Sarkis and Talluri (2002) introduced a dynamic strategic decision model based on ANP (Saaty, 1996) to help decision maker's select best supplier for their firm. Chen et al. (2006) proposed a hierarchy based MCDM model to deal with supplier selection problem. The researchers proposed the linguistic values, expressed in trapezoidal or triangular fuzzy numbers used to analyze the weights and the rate of the evaluation factors. Barla (2003) proposed a five-stage multi attribute selection model (MSM) for vendor evaluation and selection taking the case of a glass manufacturing company. Ding et al. (2005) proposed a new simulation optimization methodology to facilitate buyers in evaluation and selection of suppliers. The researchers presented a Genetic Algorithm (GA) based optimization methodology. Almeida (2007) proposed the application of ELECTRE (Elimination Et Choix Traduisant la REalite – ELimination and Choice Expressing the Reality) method for solving the supplier selection problem. The purpose of this paper is to propose a novel model for vendor selection by integrating DEA and AHP.

2. Review of the tools to be used

2.1 Data Envelope Analysis

DEA was first developed by Charnes (1978) as a mathematical programming procedure for evaluating the relative efficiencies of multiple decision making units (DMUs) that involve multiple inputs and multiple outputs. DEA measures the relative efficiency of each DMU in comparison to other DMUs. An efficiency score of a DMU is generally defined as the weighted sum of outputs divided by the weighted sum of inputs, while weight need to be assigned [1].DEA gives the highest possible relative efficiency score to a DMU while keeping the efficiency scores of all DMUs less than or equal to 1 under the same set of weights.

Initially we assume that there are k= 1 to n items of decision-making units are to be measured .Each unit has *m* inputs and *s* outputs, where X_{ij} is an input of unit j and Y_{ij} is an output *r* of unit j. Linear representation of the problem is to be given below [2]

$$E_{kk'} = \sum_{r=1}^{s} U_r Y_{rk} \quad (1)$$

m

$$\text{Stated} \sum_{i=1} V_i X_{ik} = 1 \tag{2}$$

$$\sum_{r=1}^{r=1} U_r Y_{rk} - \sum_{i=1}^{m} V_i X_{ik} \leq 1 \tag{3}$$

$U_r \geq 0$, $V_i \geq 0$, $r = 1, 2 ...s$, $i = 1, 2......m$

2.2 Analytical hierarchy process (AHP)

AHP is systematic method for using hierarchies to structure a decision problem. The first step is to determine the criteria's. AHP is a theory of measurement when dealing with both quantifiable and intangible criteria's AHP uses pair wise comparison which is more accurate than scoring methods [3]. Four steps are involved are (a) Structuring of the decision problem into a hierarchical model(b) Making pair - wise comparisons and getting judgment matrix(c) Calculation of local weights and consistency checking(d) Aggregation of weights across various levels to obtain the final weights of alternatives. Final Weight of A_i=∑ [(Local weight of A_i with respect to criterion C_j)

X (Local weight of Criterion C_j)] (4)

AHP is popular due to its simplicity, flexibility, intuitive appeal and its ability to mix quantitative and qualitative criteria in the same decision framework.

3. Proposed Framework

3.1 Use of DEA to derive local weight

DEA has been normally used for performance measurement and AHP has been applied for estimating the weights of alternatives. Some papers have applied both methods for a given problem and compared their outputs [4,5]. Research has also been done by applying DEA on pairs of units, using the resulting DEA scores to generate a pair wise comparison matrix and then applying AHP to generate weights of units from the matrix. In this paper the concept of weight measurement in AHP is integrated with the concept of efficiency measurement in DEA. I have used DEA to derive local weights from a judgment matrix. Here the entries of the matrix is used as outputs and DEA calculation cannot be made entirely with outputs and require at least one input. Hence I have introduced a dummy input that has a value of 1 for all the inputs. The efficiency score using the basic CCR model of the DEA has been used in this paper. DEA correctly calculates the true weights for a consistent judgment matrix has been proved [6]. This has been

$$\begin{array}{l c} & \begin{array}{cccc} \text{Element 1} & \text{Element 2} & & \text{Element 3} \end{array} \\ \begin{array}{l} \text{Element1} \\ \text{Element2} \\ \text{Element N} \end{array} & \begin{bmatrix} 1 & a_{12} & \cdots\cdots & a_{1N} \\ 1/a_{12} & 1 & \cdots\cdots & a_{2N} \\ 1/a_{1N} & 1/a_{2N} & \cdots\cdots & 1 \end{bmatrix} \end{array}$$

Figure 3(a) Traditional AHP

Table 1 Proposed DEA view

	Output 1	Output 2	…..	Output n	Dummy input
DMU 1	1	a_{12}	……..	a_{1N}	1
DMU 2	1/ a_{12}	1	…..	a_{2N}	1
….	…..	….	…..	…..	….
DMU N	$1/a_{1N}$	$1/a_{2N}$	……	1	1

Weights obtained by using DEA will vary from the weights that have been obtained using eigen vector method (EVM). If we want to compare with the weights derived using EVM method, then we will have to divide all the weights by the largest value. Then also we can note that there will be a difference in values. This is due to the assumptions upon on which the methods lie.

3.2 Steps to be followed

The steps involved in the proposed approach are shown in the flow chart below

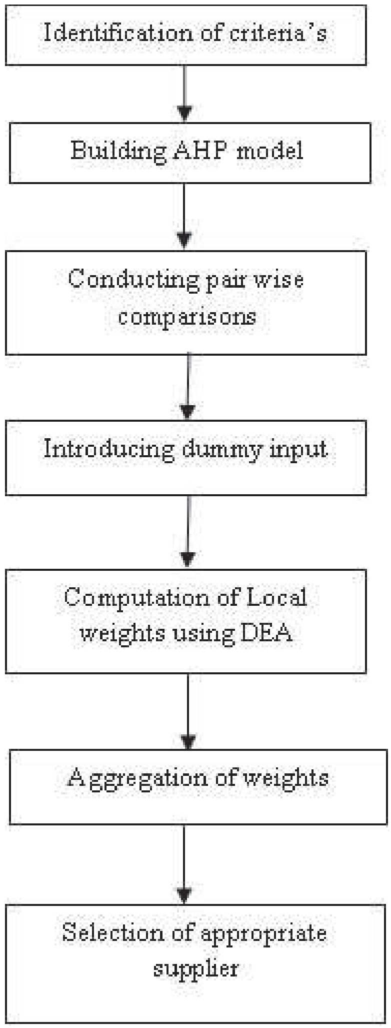

Figure 3 (b) Solution Methodology

Step 1: The problem has to be decomposed into elements according to their common characteristics. The criteria's and sub criteria's have to be identified. Hierarchy has to be formed.

Step 2: Judgment matrices have to be formed among the various levels.

Now consider a judgement matrix that is formed among the four criteria's C_1, C_2, C_3, and C_4.

Table 2 Comparison of C1, C2, C3, C4

	C_1	C_2	C_3	C_4
C_1	1	3	1/3	1/2
C_2	1/3	1	1/6	1/5
C_3	3	6	1	2
C_4	2	5	1/2	1

Step 3:

Consistency should be checked for all the matrices. For consistency checking the value of critical ratio has to be computes and checked whether the value is less than or equal to 0.1.

Critical ratio = Critical index / Random index (5)

Formula for critical Index = $(\lambda_{max} - n)/(n-1)$ (6)

$\lambda_{max} = 1/n\,[(W_1/w_1) + (W_2/w_2) + \ldots\ldots + (W_n/w_n)$ (7)

Eigen vector has to be computed for given matrix and it is denoted by w_1, w_2 ,w_3 and w_4.For matrix shown in figure 3(c) values are 0.165, 0.064, 0.479 and 0.292. Values of W_1, W_2, W_3 and W_4 are obtained by multiplying the original matrix and eigen vector. The values obtained are 0.661, 0.257, 1.942 and 1.182. The value of λ_{max} is calculated by using equation (7).

$\lambda_{max} = 1/4\,[(0.661/0.165) + (0.257/0.064) + (1.942/0.479) + (1.182/0.292)]$

$\lambda_{max} = 4.03$

The value of critical index is 0.01.Random index can be obtained for various values of n from standard table [7]. For n =4 the value of random index is 0.9

Critical ratio = 0.01/ 0.9

Critical ratio = 0.011< 0.1. The matrix formed is consistent.

Step 4:

Dummy input has to be introduced in the judgment matrix.

Table 3 : Output input structure of DEA

	Output 1	Output 2	Output 3	Output 4	Dummy input
C_1	1	3	1/3	1/2	1
C_2	1/3	1	1/6	1/5	1
C_3	3	6	1	2	1
C_4	2	5	1/2	1	1

Step 5:

Next is conversion into linear programming .Basic CCR model of DEA is used.

Max $Z = V_1+3V_2+0.33V_3+0.5V_4$

Subject to $U_1=1$

$V_1+3V_2+0.33V_3+0.5V_4 - U_1 <= 0$

$0.33V_1+V_2+0.167V_3+0.2V_4 - U_1 <= 0$

$3V_1+6V_2+V_3+2V_4 - U_1 <= 0$

$2V_1+5V_2+0.5V_3+V_4 - U_1 <= 0$

$V_1, V_2, V_3, V_4 >= 0$

Step 6:
Equations have to be formed using specialized DEA software and values of DEA efficiency can be obtained.
Step 7: Aggregation should be carried out using the normal procedure involved in AHP and final weight of the alternatives should be calculated and rank the alternatives in the descending order of their weights.

4 Case Study

A fish net manufacturing company is taken as a case for implementation of the proposed model. The case study demonstrates the effectiveness and usefulness of the proposed methodology. The organization taken for case is a famous manufacturer of fish net, established during 1986 and located in South India. Due to the competing market, the company has to formulate various strategies to improve the customer service level. It has decided to adopt a effective vendor selection methodology. The organization's ability to generate profits will guide the industrial circles in which it competes.

A team reviewed the candidate suppliers according to the evaluation criteria's and after this evaluation , capable suppliers were identified and added to the approved supplier list of the company. The proposed decision model of vendor selection was implemented for 19 criteria under three main criteria cluster and three main alternative suppliers.

4.1Problem definition

There are three potential vendors Alternative1, Alternative 2, Alternative 3.The Company has collected the details of the vendors by thorough investigation. The problem is to identify one efficient supplier among the three.

4.2Application of methodology for the case study

Step 1: This step involves identification of criteria's and establishing the hierarchical structure.
The critical selection criteria's are cost, supplier profile, Risk management, Long term relationship, service.

Table 4: The selection criteria

Selection Criteria	Explanation	Reference
Cost	It refers to the total cost involved and it has to be reduced.	Spencer *et al.* (1994)
Supplier profile	It considers background information of the vendor like Market Share, financial viability etc.	Konstantinos Kirytopoulos *et al.* (2008)
Risk management	It refers to the capability of the vendor to address any unforeseen problem.	Boyson *et al.* (1999)
Long term Relationship	Factors affecting the compatibility are considered.	Boyson et al (1999)
Service	The extent to which a vendor satisfy quality requirements are considered.	Konstantinos Kirytopoulos *et al.* (2008)

Based on the opinion of experts in the organization, 19 critical selection sub criteria are identified for the evaluation and selection of vendor. The sub criteria's are explained below in table 3.

Table 5: Selection sub criteria

Selection Criteria	Explanation	Reference
Price	It denotes the unit price of the product.	Gol and catay (2007)
Freight	Transportation cost.	Konstantinos Kirytopoulos *et al.* (2008)
Flexibility in billing	Good will is improved.	Bradley (1994)
Financial	It includes the market share, profit generated	Liu and bang (2009)

Performance		
Production facilities	Physical equipment, capacity utilisations are Considered.	Cevriye Gencer *et al.* (2007)
Technology & Innovation	Up gradation of technology	Buyukozkan *et al.*(2008)
Surge capacity	Ability of the vendor to satisfy sudden rise in demand.	Anonymous (1999)
Delivery delay	It refers to the expertise in delivery performance.	Stock *et al.* (1998)
Wrong Quantification	Number of piece counts should be exact as promised.	Konstantinos Kirytopoulos *et al.* (2008)
Attitude	The willingness to cooperate with the firm is considered.	Razzaque and Sheng
Trust & fairness	It is concerned with maintain confidentiality.	Rajesh *et al.* (2009 b)
Information sharing	It refers to the readiness to share information.	Tate (1996)
Employee Satisfaction level	Presence of dissatisfied employees may affect service.	Langley *et al*. (2003)
Quality	Extent to which the product specification are met	Konstantinos Kirytopoulos *et al.* (2008)
Flexibility in Operations & delivery	It denotes the ability of the vendor to provide customized products.	Sink and Langely
Value added Services	It denotes the ability to provide services like training.	Konstantinos Kirytopoulos *et al.* (2008)
Lead time	The time required for filling the order	Ozden Bayazit
Packaging ability	It refers the ability to pack the products effectively.	Meade and sarkis (2002)

Step 2: Pair wise comparisons should be formed at various levels. All together 25 pair wise comparison matrices are formed.
Step 3: Consistency has to be checked. After calculating the value of Eigen vector critical ratio has to be computed using the equations 5, 6, and 7.
Step 4: Conversion to DEA format involves introduction of dummy input 1 in all the matrices. All the other entries have to be converted into output.
Step 5: Convert all the data into linear programming models. CCR model is employed.
Step 6: Using specialized DEA software efficiency values are obtained. The values are given below

Table 6: Efficiency score of main criteria's

Criteria	Efficiency
Cost	0.286
Supplier profile	0.571
Risk mgt	0.857
LTR	0.143
Service	1.0

From the table it is clear that service is the most important criteria that affect vendor selection.
Similarly efficiency score of sub criteria's and the weight of individual alternatives for all the criteria's are obtained.
Step 7: Aggregation of weights is done using equation 4 and weights of alternatives are found out.

Ranking has been done based on their weight. The weight and ranking are given below

Table 7: weight of Alternatives

Alternatives	Weight	Rank
A1	3.131	III
A2	6.086	I
A3	5.271	II

The vendor A2 is selected.

4.3 Issues to be considered

- DMUs should be homogeneous units. The inputs and outputs should be identical
- If the number of inputs and outputs are much larger than the number of DMUs, the discriminating power of DEA will be affected.
- For a single judgment matrix, many linear programming problems have to be solves resulting in more computational work but use of specialized software reduces the work.

Conclusion

DEA has been utilized for deriving weights from the judgement matrix. If an alternative is removed from consideration, the ordering remains unaltered i.e. the rule of independence of irrelevant alternatives is satisfied. The main reason is that the weights for alternatives are calculated using separate linear programming models. In DEA the ranking is calculated with respect to an efficient alternative and if an inefficient alternative is removed the ordering remains unchanged. The main advantage of the proposed model is that rank reversal problem that exists in AHP doesn't occur in the new model.

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